Survey of the reptiles of the montane forests near Dorrigo on the north coast of New South Wales

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ABSTRACT

Reptile surveys were conducted in the early 1990s in the Dorrigo Forest Management Area, an area formerly comprising timber-production forests managed by the Forestry Commission of New South Wales. The surveys consisted of searches for reptiles along 54 transects together with targeted surveys. Twenty-two 500 m transects were located in previously logged forest and 32 in unlogged forest. Each transect was surveyed twice at an average seven days apart in the spring-summer of 1993 by two persons simultaneously for a duration of 90 min each. A total of 26 reptile species were detected during systematic surveys and 22 reptile species during targeted diurnal searches and opportunistic sightings. The highest species richness and density of reptiles were recorded in the logged New England Hardwood and Gorge Red Gum forest types. The Moist Hardwood type, with a closed mid-canopy had the lowest reptile species richness and density. Neither species richness nor number of individuals varied significantly with logging history. Analysis of abundances of two species of skink that accounted for 88% of detections during transect searches found that the Grass Skink *Lampropholis delicata* was more abundant in logged sites and during the second survey, whereas the Scute-snouted Calyptotis *Calyptotis scutirostrum* had higher densities in unlogged sites and in the first count. However, species richness did not vary significantly with logging history, forest type or count. Stephens' Banded Snake *Hoplocephalus stephensii,* listed under the *TSC Act (1995),* was observed in the survey area by State Forests' staff. Another 15 species of reptiles recorded during surveys are considered as conservation priority species (Scotts 1996). The Major Skink *Bellatorias frerei* had not previously been recorded in the survey area and represented a southern range extension. The survey was unable to assess the impacts of logging on threatened species because of low numbers detected. Approaches to improve this situation in future surveys are discussed.

Key words: Dorrigo Forest Management Area, reptiles, impacts of logging, herpetofauna, logging, wet sclerophyll forest, rainforest

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Introduction

In the early 1990s, the then Forestry Commission of New South Wales FCNSW conducted a series of surveys of timber-production forests under its management. These surveys were intended to assess the impacts of logging activities through Environmental Impact Statements (EISs). While the ability of these surveys to accurately assess such impacts has been questioned (Resource Assessment Commission 1993, Milledge 1993, Newell and Goldingay 2004, Daly and Lemckert 2011), they did provide regional surveys of the fauna and flora and valuable quantitative baseline data. One of the areas of forest surveyed was located in the Dorrigo area (Dorrigo Forest Management Area (FMA)) of the north-eastern escarpment of New South Wales (Countrywide Ecological Service 1995). The EIS surveys remain the only substantial assessment of the reptile fauna of forests in this region and provide a large data set on which to base our knowledge of the biodiversity in the region.

The aim of the present paper is to document the reptile species that were detected during the EIS surveys in the early 1990s and provide information on their broad locations and habitat associations in the Dorrigo FMA. We review the survey methodology used in terms of its robustness in assessing the impacts of logging on forest-dependant species. We present the distributions of reptiles in each state forest within the Dorrigo area and reinterpret the findings. We also consider past and current forestry management practices, particular in regard to conservation of species listed under the *Threatened Species Conservation (TSC) Act (1995)*. The distribution, species richness and relative abundance of reptiles was quantified at a given time by the use of a systematic survey methodology.

Methods

Location of survey area

The survey area lies within the former Dorrigo FMA, situated on the north coast of New South Wales between 29° 55' and 30° 15'latitude and 152°25' and 152°50' longitude (Figure 1; Countrywide Ecological Service 1995). The total area covered was approximately 80,000ha and included Chaelundi, Ellis, Wild Cattle Creek, Marengo, Moonpar, Hyland and Bielsdown State Forests (SFs). While the altitudinal range of the State

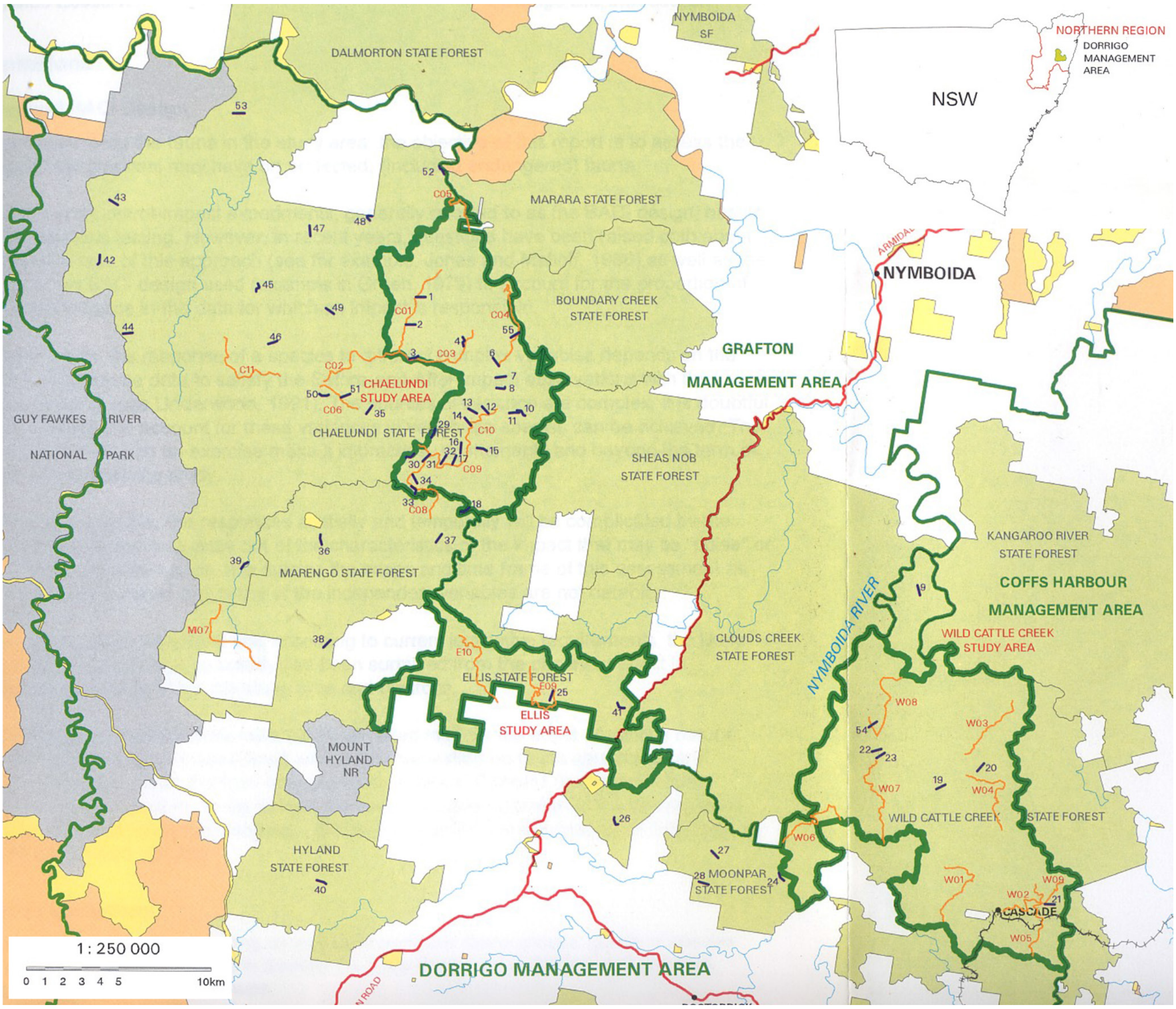

Figure 1. Location of the reptile transects surveyed in the Dorrigo management area with grey indicating National Parks and green indicating State Forests in 1993.

Note: significant expansion transfer of State Forest tenure to National Parks took place in the late 1990s.

Note: the numbers of the transects do not correspond to the site numbers in Appendix 1.

Forests varied between 200-1100 m ADH, the majority of survey sites were located about 800 m AHD. Some of these areas are now included in the NSW reserve system as a result of the Upper and Lower North East Forests Regional Forest Agreement (RFA) (Table 1).

Geology and soils

The soils in the survey area were derived from three main geologies, dominated by deformed siltstones, metamorphosed and interrupted volcanics and granite outcrops, especially along the ridges (Drielsma 1995). The most fertile soils were derived from volcanics and the least fertile from granites.

Forest types and Associations

Broad forest types varied from closed forest (rainforest) to open forest. Descriptions of forest types and associations are based on field observations and Binns (1995). Although no systematic surveys were conducted in closed forest, a number of targeted searches were undertaken in this habitat. The closed forest either comprised subtropical, dry or cool rainforest associations. In the subtropical rainforest the canopy species included Yellow Carrabeen *Sloanea woollsii*, Giant Stinging Tree *Dendrocnide excelsa* and Black Booyong *Heritiera actinophylla*. The dry rainforest was dominated by Hoop Pine *Araucaria cunninghamii*, Grey Myrtle *Backhousia myrtifolia* and/or Ironwood *B. sciadophora*. The cool rainforest was dominated by Antarctic Beech *Nothofagus moorei*. The ground cover was dominated by ferns such as *Adiantum hispidulum*, *Blechnum cartilagineum*, *Doodia aspera*, *Pellaea falcata var.* nana and *Pteris umbrosa*.

Closed forest also occurred in the mid-canopy of some of the Moist Hardwood forest type, which was dominated by Brushbox *Lophostemon confertus*, Tallowwood *Eucalyptus microcorys* and Blue Gum *E. saligna*. The mid-canopy contained rainforest species such as Soft Corkwood *Caldcluvia paniculosa*, Murrogun *Cryptocarya microneura*, Forest Maple *C. rigida*, Tree Heath *Trochocarpa laurina*

Table 1. Areas and subsequent reservation areas of State Forests surveyed, elevational range, and numbers of reptile survey sites in the Dorrigo Forestry Management Area.

Note: area of State Forest represents that identified in the EIS and may not represent the total area of the Forest. (n) = number of logged sites

State Forest	Area (ha)	Area (ha) added to State reserve system	Number of reptile sites	Min. elevation (m AHD)	Max. Elevation (m AHD)
Chaelundi	8277	1059	36 (9)	200	930
Ellis	3977	868	3 (3)	505	1100
Wild Cattle Creek	13444	1960	7 (4)	260	760
Marengo	18000	635	4 (4)	650	830
Moonpar	821	585	3 (2)	590	690
Hyland	248	248	1 (0)	1010	1010
Bielsdown	945	945	none		
Total	c. 80000	6300	54 (22)		

and Crab Apple *Schizomeria ovata*. The ground cover was dominated by ferns such as *Blechnum cartilagineum* and *Lastreopsis decomposita.*

The Blackbutt forest type comprised Blackbutt *E. pilularis* in association with Tallowwood *E. microcorys,* Blue Gum *E. saligna* and New England Blackbutt *E. campanulata.* Turpentine *Syncarpia glomulifera* was also common at some sites. The mid-canopy included rainforest species and in drier sites grass trees *Xanthorrhoea malacophylla* were present. The ground cover species varied with fire history but included *Blechnum cartilagineum,* Blady Grass *Imperata cylindrica, Pteridium esculentum, Poa sieberiana* and *Hibbertia scandens.*

New England Hardwood was dominated by New England Blackbutt *E. campanulata*, frequently in association with Tallowwood. The mid-canopy and understorey of this type included species such as Soft Corkwood, Bastard Rosewood *Synoum glandulosum* and Black Wattle *Callicoma serratifolia*. The ground cover included species such as Blady Grass and Kangaroo Grass *Themeda australis.*

The Spotted Gum type was dominated by Spotted Gum *Corymbia maculata,* but frequently had Thick-leaved Mahogany *E. carnea,* Grey Gum *E. biturbinata,* Grey Ironbark *E. siderophloia* and Tallowwood present as sub-dominants. The mid-canopy and understorey were sparse, comprised mostly of Forest Oak *Allocasuarina torulosa*. The ground cover included species such as Blady Grass and Kangaroo Grass. As with other open forest types, the grassy understorey of Spotted Gum was subject to occasional grazing and regularly burning.

Dry Hardwood included a range of associations including Thin-leaved Stringybark *E. eugenioides,* Forest Red Gum *E. tereticornis,* White-topped Box *E. quadrangulata,* Grey Gum, Thick-leaved Mahogany and Pink Bloodwood *Corymbia intermedia.* The dense ground cover was dominated by *Poa sieberiana* and Kangaroo Grass.

Gorge Red Gum was dominated by Forest Red Gum *E. teriticornis*, Thin-leaved Stringybark and the occasional Pink Bloodwood. This forest type was heavily grazed and the ground cover was characterised by exotic grasses.

The Scribbly Gum forest type was dominated by Scribbly Gum *E. signata* with White Mahogany *E. acmenoides,* Thin-leaved Stringybark, Red Mahogany *E. resinifera* and Broad-leaved Apple *Angophora subvelutina* as sub-dominants. The ground cover species included Kangaroo Grass, *Lomandra filiformis* and *Entolasia stricta.*

Forest management

Forests in the survey area have been logged since 1857 (Drielsma 1995) to varying intensity. Early selective logging (1906-1930) was generally less intense than practices in the 1980's and early 1990's and focused on extraction of Red Cedar *Toona ciliata*, then Hoop Pine (Curby 1994). After 1930 there was a change to other rainforest species and hardwoods (eucalypts). By the 1940's logging was focused on hardwoods and some areas were re-logged in the 1960's (Drielsma 1995). The average annual production of hardwood sawlogs increased from approximately 33,000 cubic metres in the 1960's to approximately 56,000 cubic metres in the 1990's (Table 5-2, Drielsma 1995). The average annual production of various grades of hardwood sawlogs has decreased in the last decade (from 56,000m^3 to about 50,000m^3) due to transfer of substantial areas of State Forests to National Parks. However, the main change since the 1990's is that about half of the volume is sourced from plantation timber (D. McLean unpub. data).

Early silvicultural management of the forests was aimed at maintaining a nearly continuous mature tree canopy by restricting tree removal in any one harvesting cycle to 15% of the upper canopy (Drielsma 1995). At the time of the survey the cutting cycle (re-logging) was approximately 40 years (Countrywide Ecological Services 1995) and additional silvicultural methods such as gap creation were being practiced. Disturbance within these gaps to enhance eucalypt regeneration is achieved by logging machinery and post-logging burning. Approximately 45% of the survey area was subject to grazing permits at the time of surveys, with about 13% of the area representing Crown lease.

Various harvesting prescriptions had been adopted by the then FCNSW to avoid impacts on specified forest and other vegetation types and in areas where threatened species of fauna (as listed under former Schedule 12 of the then *National Parks and Wildlife Act 1974)* had been detected. In general rainforest, some old growth, flora reserves and wildlife corridors such as riparian habitat, habitat trees, as well as a range of other features were excluded from logging.

Approximately 15-20% of the volume of logs removed was to be retained as ground debris or logging slash (represented by stumps and tree heads) and/ or standing timber for habitat purposes (Drielsma 1995).

Survey methods for reptiles

The methodology used for surveys was devised by the FCNSW (York *et al.* 1991) with the main effort being centred around 54 x 500 m long transects placed within broad forest types as determined by FCNSW and further categorised as logged or unlogged (Tables 1 and 2). The use of canopy species to determine forest type meant that the survey also sampled reptile species richness and density in relation to environmental variables such as soil moisture content that were reflected by the varying forest types. Transects were separated by a minimum of 800 m and located within 50-100 m of access roads. The location (Geocentric Datum of Australia 94) of sites was taken from topographic maps (Appendix 1).

Transect surveys for reptiles were conducted between 0835-1530 h EST between the 28th September and 3rd of December 1993. Two observers simultaneously walked along each transect to search 15 metres either side of a nine point midline. Reptiles were observed as they basked or foraged or by lifting loose rocks and logs, decorticating bark and searching leaf litter to uncover individuals. Each transect search took 90 min, amounting to a total of 180 min search effort per transect and covering approximately 1.5 ha. Each site was surveyed twice with the second search occurring between one and 28 days after the initial survey, with an average of approximately 7 days separating searches of sites. The two surveys provided a more robust data set and information on disturbance (species richness) resulting from the survey. A total of 324 person/hrs (54 transects x 2 x 2 observers) was spent searching transects for reptiles.

Targeted searches were conducted at various locations, especially granite outcrops in Chaelundi SF to find reptiles under exfoliating rock. Targeted searches were also conducted in Bielsdown SF. Reptiles were also recorded opportunistically while conducting nocturnal frog searches and driving on roads and tracks travelling to and from survey sites.

Analysis of reptile transect survey data

For each 90 min 500 m transect search the total number of reptile species detected and the total numbers of individuals of each species were tallied (Table 3, Appendix 1). This allowed a statistical analysis of the two most abundant species, species richness with respect to logging history and forest type and a comparison between the first and second survey. The mean species richness of reptiles detected during the 90 min transect surveys was tallied in relation to forest types and logging history (Table 4). A checklist of reptile species recorded from various surveys within State Forests of the Dorrigo Forestry Management Area was prepared (Appendix 2).

RESULTS

Reptile transect surveys

The two 180 min searches along the 54 transects (Table 3) detected 3270 individuals of 26 species during 324 hours. Targeted searches and opportunistic observations revealed an additional 22 species (Appendix 2). Records of *Concinnia martini* and *C. tenuis* were combined as the first of these species was not identified as taxonomically distinct by some surveyors at that time. Two species dominated the results in regard to overall abundance. The Grass Skink *Lampropholis delicata,* accounted for 64 % of all observations and the Scute-snouted Calyptotis *Calyptotis scutirostrum* accounted for 24 % of observations. Four transects were partially burnt and another four had recently been burnt.

Snakes, goannas, geckoes, legless lizards and dragons were infrequently detected. One species of goanna (Lace Monitor *Varanus varius*) one species of gecko (Moritz's Leaftail Gecko *Saltuarius moritzi*), one species of legless lizard (Burton's Snake-lizard *Lialis burtonis*) and two species of dragon (Nobbi Dragon *Amphibolurus nobbi nobbi* and Forest Dragon *Hipsilurus spinipes*) were recorded. Four species of elapid snake (Small-eyed Snake *Cryptophis nigrescens*, Yellow-faced Whip Snake *Demansia psammophis,* Swamp Snake *Hemiaspis signata,* Red-bellied Black Snake *Pseudechis porphyriacus*) and one blind snake (*Ramphotyphlops nigrescens*) were found. One Swamp Snake of the uncommon melanotic colour phase was recorded. One specimen of the threatened, Stevens' Banded Snake *Hoplocephalus stephensii* was found by Forestry staff in dry Blackbutt forest.

Reptile species richness ranged from 0-7 species per transect. The average species richness was not significantly different with respect to forest type (Kruskal-Wallis non parametric test, H = 0.722, 1 d.f., P=0.40) or logging history (Mann-Whitney U test, Z=0.195, 1 d.f., P=0.66).

Table 2. Numbers of logged and unlogged sites surveyed in different forest types in the Dorrigo FMA

Forest type	Number of unlogged sites	Number of logged sites	Total sites
Spotted Gum	6	6	12
Dry Hardwood	6	0	6
Moist Hardwood	6	6	12
New England Hardwood	6	2	8
Blackbutt	6	6	12
Gorge Red Gum	0	2	2
Scribbly Gum	2	0	2
Total	54	22	

Table 3. Species of reptiles detected during the two 90min transect surveys within State Forests of the Dorrigo Forestry Management Area.

Note: some of the surveys did not differentiate between the Dark Bar-sided Skink *Concinnia martini* and the Barred-sided Skink *C. tenuis*. The Dark Bar-sided Skink was common but the Barred-sided Skink was rarely detected and survey results for both species are combined under the Dark Bar-sided Skink. Numbers of transects represents the number of transect surveys (including repeat surveys) on which a species was detected. * indicates conservation priority species as per Scotts (1996)

Family	Species	Common Name	Chaelundi	Ellis	Wild Cattle Creek	Marengo	Moonpar	Hyland	No. Of Transects	No. Of Individuals
Varanidae	*Varanus varius*	Lace Monitor	2						2	2
Gekkonidae	*Saltuarius moritzi**	Moritz's Leaftail Gecko	1		1				1	2
Pygopodidae	*Lialis burtonis*	Burton's Legless Lizard	1						1	1
Agamidae	*Amphibolurus nobbi nobbi*	Nobbi Dragon	8						6	8
	*Hipsilurus spinipes**	Forest Dragon		2					1	2
Scincidae	*Bellatorias major*	Land Mullet	1		1				2	2
	Carlia vivax	Lively Rainbow Skink	1						1	2
	*Calyptotis scutirostrum**	Scute-snouted Calyptotis	671	34	39	50	5		80	799
	*Concinnia martini/ tenuis**	Dark Bar-sided Skink	22		1	3			15	33
	*Concinnia murrayi**	Blue-flecked Forest Skink	3		13	3	2		12	21
	Cryptoblepharus pulcher	Elegant Snake-eyed Skink	2						2	2
	Ctenotus taeniolatus	Copper-tailed Skink	1						1	2
	*Egernia mcpheei**	Eastern Crevice Skink	10		1				8	11
	Eulamprus quoyii	Eastern Water Skink	15			21			13	36
	Lampropholis amicula	Friendly Skink	34					1	12	34
	Lampropholis delicata	Grass Skink	1436	164	160	136	139	73	91	2108
	Lampropholis guichenoti	Garden Skink						2	1	2
	*Ophioscincus truncatus**	Short-limbed Snake-skink	1	2	11				7	14
	Saiphos equalis	Three-toed Skink	29	2	8	49	2	28	25	143
	Saproscincus spectabilis	Gully Skink	6	7	6		3		11	22
Elapidae	*Demansia psammophis*	Yellow-faced Whip Snake	9			1			8	10
	Hemiaspis signata	Swamp Snake		1	1				2	2
	Pseudechis porphryiacus	Red-bellied Black Snake	2						2	2
	Cryptophis nigrescens	Small-eyed Snake	4		1				4	5
Typhlopidae	*Ramphotyphlops nigrescens*	Black Blind Snake	4	1					4	5
		Total Species	22	8	12	7	5	4		
		Total Individuals								3270
		Total Sites	36	3	7	4	3	1	54	

Table 4. Mean species richness of reptiles detected during the 90min transect surveys in relation to forest types and logging history in the Dorrigo Forestry Management Area. (N) = number of sites

Community	Unlogged sites	Logged sites	Average
Spotted Gum	3.1(6)	2.9(6)	3.0
Dry Hardwood	3.0(6)	0	3.0
Moist Hardwood	2.3(6)	2.2(6)	2.2
New England Hardwood	2.8(6)	3.5(2)	3.2
Blackbutt	3.1(6)	2.3(6)	2.7
Gorge Red Gum	0	3.5(2)	3.5
Scribbly Gum	2.8(2)	0	2.8
Average	**2.9(32)**	**2.9(22)**	**2.9**

The highest average species richness was found at logged sites in the New England Hardwood and Gorge Red Gum forest types and the lowest species richness was at sites in logged and unlogged Moist Hardwood and Blackbutt forest types (Table 4). The total number of individual reptiles observed ranged from 0 – 165 per transect and did not vary significantly with logging history (Mann-Whitney U test, Z=0.195, 1 d.f., P=0.66), but was significant between forest types (Kruskal-Wallis non parametric test, H=37.139, 6 d.f., P <0.001). Higher numbers of individuals were recorded in Spotted Gum and dry hardwood forests. Higher numbers of individuals were recorded during the second survey compared with the first (1457 vs 1738, Appendix 1), but this result was not significant (Mann-Whitney U test, Z=0.348, 1 d.f., P=0.56). The total number of species detected during the second survey was also higher than that during the first survey (pooled means 2.6 vs 3.0), although again, this also was not statistically significant (Mann-Whitney U test, Z=1.83, P=0.07).

Analysis of records of common reptile species

The number of Grass Skinks observed during individual transect searches ranged from one to 154 individuals. Grass Skinks were detected on most transects (49 of 54, 91%) and were more abundant at sites that were logged (pooled means 24 vs 15 individuals) and in the second survey (884 vs 1132 individuals), but the numbers observed were not significantly different between logging histories (Mann-Whitney U test, Z=1.601, 1 d.f., P=0.21) or between the two surveys (Mann-Whitney U test, Z=1.310, 1 d.f., P=0.25). The number of Grass Skinks did, however, vary significantly between forest types (Kruskal-Wallis non parametric test, H=36.352, 6 d.f., P<0.001) with the highest numbers detected at sites in logged Blackbutt and Spotted Gum forest types (Table 5). The lowest numbers were found in the Moist Hardwood forest type with slightly fewer at unlogged v. logged sites. In general, there was a trend for higher densities of Grass Skinks in forests that had an open subcanopy. Scute-snouted Calyptotises were detected on 67% of transects. The number of Scute-snouted Calyptotises varied significantly between forest types (Kruskal-Wallis non parametric test, P <0.001), with the highest observed densities in the unlogged Dry Hardwood forest type and the lowest in the Moist Hardwood forest type (Table 5). The number observed did not vary significantly in respect of logging history (Mann-Whitney U test, Z=1.736, 1 d.f., P=0.19) or between the two surveys (Mann-Whitney U test, Z=0.475, 1 d.f., P=0.49).

Targeted searches of specialised habitats and opportunistic observations

The Eastern Long-necked Turtle *Chelodina longicollis,* Macquarie River Turtle *Emydura macquarii*, Common Scalyfoot *Pygopus lepidopodus,* Eastern Water Dragon *Intellagama lesueurii*, Three-clawed Worm Skink *Anomalopus verreauxii*, Striped Skink *Ctenotus robustus*, Pink-tongued Lizard *Cyclodomorphus gerrardii*, Beech Skink *Harrisoniascincus zia*, Eastern Blue-tongued Skink *Tiliqua scincoides*, Carpet Python *Morelia spilota mcdowellli*, Common Tree Snake *Dendrelaphis punctulatus*, Golden Crown Snake *Cacophis squamulosus* and Rough-scaled Snake *Tropidechis carinatus* were detected during targeted surveys of Chandler's River, closed forests (rainforest

Table 5. Pooled average counts of the Grass Skink *Lampropholis delicata* and Scute-snouted *Calyptotis Calyptotis* scutirostrum in logged and unlogged transects in the Dorrigo Forestry Management Area

Note: only sites with six replicates of similar forest types and logging history (Table 4) used for analysis

Community	Pooled average *L. delicata* in unlogged sites	Pooled average *L. delicata* in logged sites	Pooled average *C. scutirostrum* in unlogged sites	Pooled average *C. scutirostrum* in logged sites
Spotted Gum	34.5	37.1	9.3	3.7
Dry Hardwood	8.6	-	20	-
Moist Hardwood	3.3	3.9	2.4	0.2
New England Hardwood	15.2	-	7.2	-
Blackbutt	16.3	40.3	6.3	1.3

habitat) and while driving. Nine species were observed during searches of granite outcrops, they included Moritz's Leaftail Gecko *Saltuarius moritzi*, Common Scalyfoot, Red-throated Skink *Acritoscincus platynota,* Eastern Crevice Skink *Egernia mcpheei,* Eastern Water-skink *Eulamprus quoyii*, Grass Skink, Whites Skink *Liopholis whitii*, Three-toed Skink *Saiphos equalis* and Small-eyed Snake *Cryptophis nigrescens* (Appendix 2)

Discussion

Species richness and density

This survey recorded 48 species of reptiles within the former Dorrigo FMA. This represents a higher tally of species than that recorded during surveys for other parts of the north-eastern NSW such as the adjacent Gibraltar Range National Park (NP) where 32 species of reptiles were recorded (Barker 1981) or further north in the Tenterfield FMA where 33 species of reptiles were detected (Daly and Lemckert 2011). The Dorrigo plateau is clearly a species rich region for reptiles. A consequence of the findings of this survey and other data, the RFA process resulted in some 6300 ha of State Forest in the Dorrigo FMA being added to the State reserve system (Table 1), facilitating the protection of reptiles in this area.

Two species of legless lizard detected during the current survey were Burton's Snake-lizard and the Common Scalyfoot. The low density of legless lizards recorded was probably a reflection of their natural population density and is consistent with results of other studies in the region (Daly and Lemckert 2011, Barker 1981). Many of the species that Barker (1981) detected in the Washpool area were also found in the Dorrigo FMA including Moritz's Leaf-tail Gecko, Major Skink *Bellatorias frerei,* Alpine Water Skink *Eulamprus kosciuskoi* and Eastern Tiger Snake *Notechis scutatus.* Most of these were recorded throughout the region during the North East Forests Biodiversity Study (NSW NPWS 1994 a,b,c).

Threatened (*TSC Act 1995*) and conservation priority reptile species

As noted above, one threatened (*TSC Act 1995*) reptile, the Stevens' Banded Snake was detected by Forestry staff. The surveys also recorded 15 conservation priority species listed by Scotts (1996) (Appendix 2).

Impacts of logging

The impacts of logging on reptiles was examined through an analysis of the survey transect data also used in the Dorrigo EIS (Countrywide Ecological Services1995). However, some of the conclusions drawn from the previous analysis may have been confounded by factors such as grazing and associated burning (Drielsma 1995) and also because pooled abundance data (total number of reptiles observed), as used in much of the Dorrigo EIS, are typically dominated by a small number of common species (Goldingay *et al.* 1996 Newell and Goldingay 2004, Daly and Lemckert 2011).

In this survey the Grass Skink and Scute-snouted Calyptotis accounted for 88% of the observations, hence analysis of total abundance would be dominated by the response of these species. For this reason we analysed the impacts of logging solely on these species. The methodology of York *et al.* (1991) is sound for common species, especially with regard to the amount of survey effort, including repeating each transect survey. In this study the number of replicate sites selected for the Spotted Gum, Moist Hardwood and Blackbutt forest types were valid for analysis. Other variables likely to affect our results included variation within a forest type (moisture regime) along a transect and the varying intensity of logging between sites. Variation in habitat would be expected to increase the species diversity on any transect. Unfortunately these variations were not measured.

Overall, the results from this survey suggested that logging and even disturbance from reptile searches increased population densities of the Grass Skink, but had no significant impact on the Scute-snouted Calyptotis (Appendix 1). The non-significant reduction in abundance with logging of Scute-snouted Calyptotis may be related to the fossorial habit of this species. Daly and Lemckert (2011) found a similar result for these two species in the Tenterfield FMA, suggesting this may be a common response to logging with these species.

The increase in densities of some skink species following logging has been attributed to increased solar radiation and the abundance of logging slash (logs/branches/stumps) and litter following logging (Daly and Lemckert 2011, Goldingay *et al.* 1996, Lunney *et al.* 1991). In this survey, the impact from disturbance from reptile searches also appeared to have led to an increase in detectability of the Grass Skink, because greater densities were found in the second survey (Appendix 1). This may be because disturbance from surveys could provide additional foraging substrate or even food being made available. This species has a broad distribution in eastern New South Wales (Swan *et al.* 2004) and is the most abundant species in many areas (Daly and Lemckert 2011, Daly 2007, Daly 2006, Wellington and Wells 1995, CSIRO Division of Wildlife and Ecology 1996, Austeco Environmental Consultants 1994, Smith *et al.* 1994, 1995, Clancy 1992). The abundance of the Grass Skink has biased statistical analysis of pooled total abundance data used to gauge the impacts of logging in many impact assessments (Austeco Environmental Consultants 1994, Clancy 1992, Mt King Ecological Services 1995). Several reports (Smith *et al.* 1994 and 1995, CSIRO Division of Wildlife and Ecology 1996) did not attempt logging impact analyses based on total abundance as the authors identified the problem of bias resulting from the influence of large numbers of a few common species.

Our finding that average reptile species richness was not significantly different with respect to forest type or logging history was not unexpected. This result was also found by a number of impact assessments to gauge the impacts of logging (Austeco Environmental Consultants 1994, Clancy 1992, Countrywide Ecological Services 1995, Goldingay *et al.* 1996, Mt King Ecological Services 1995, Smith *et al.* 1992, Wellington and Wells 1995). One previous assessment found a significant difference in species richness in respect to forest type (Ecotone

Ecological Consultants 1995). The lack of significant effect of logging on species richness suggests logging, as practiced in northern NSW up until the 1990s, did not have a large impact on the reptile community, although species richness does not take into account the actual abundance of individual species. This means that subtle effects such as the declines in the abundance of individual species will not be represented. Hence the non-abundant species could have reduced populations following logging, but this is not represented solely using species richness.

The main reason for assessing the impacts of logging in NSW State Forests at the time of the survey was to comply with legislative requirements in assessing the effects on Threatened (*NPW Act 1974*) species. The only Threatened reptile species known from the Dorrigo FMA, Stephens' Banded Snake was not found during surveys but had been observed by State Forest staff prior to the survey period. This forest-dependent, largely arboreal snake (Fitzgerald *et al.* 2004) occurs at such low densities (Fitzgerald *et al.* 2002) that the systematic survey methodology adopted was unlikely to detect this species. The lack of such quantitative data on Threatened species was a constant problem for logging impact assessments during the Forestry EIS process. Radio-tracking studies such as the one conducted on Stephens' Banded Snake may provide more useful information on logging impacts of rare and arboreal species.

Forest management

No set of specific habitat protection measures were prescribed in the EIS for the Stephens' Banded Snake and none have been designated and applied since that time. Fitzgerald *et al.* (2004) state that disturbances such as logging, fire and grazing are likely to affect the snake and its prey species. We considered that this was a major failing of Threatened species management in the FMA. Existing management criteria including protection of riparian areas, the exclusion of logging in rainforest and old growth, retention of habitat trees and over ridge connection corridors would, however, have assisted in protecting significant habitat used by this species, but it is not known whether this is sufficient to maintain the Stephens' Banded Snake in the Dorrigo FMA.

Countrywide Ecological Services (1995) recommended that grazing be discontinued in the FMA as the practice was associated with a major increase in fire frequency. Grazing leases still exist within Dorrigo State Forests and undoubtedly uncontrolled burns continue. At the time of the survey, the timber cutting cycle was approximately 40 years (Countrywide Ecological Services 1995), but since that time the cycle has been halved to about 20 years (Forests NSW 2012, 2013, Forestry Corporation of NSW 2014).

The reduction in cutting cycles increases disturbance (particularly from burning) in the FMA and may reduce the number of important habitat attributes such as hollow-bearing trees (McLean *et al.* 2015, Gibbons *et al.* 2000) and large fallen logs (McLean 2012), potentially negatively impacting on the region's reptile fauna. Conversely, Collins *et al.* (2012), found the number of fallen logs increased with logging intensity, due to unmerchantable timber being left in situ. The increase in fallen logs would only occur over a few cutting cycles within the Dorrigo FMA, especially since there has been a shift to plantation timber.

Species that respond positively to disturbance and elevated levels of direct sunlight (heliothermic) may be advantaged by this increase in disturbance (Alexander *et al.* 2002), but species that are forest-dependant (thigmothermic and requiring hollows in standing or fallen trees) are likely to have been disadvantaged (Theisinger and Ratianarivo 2015).

Assessment of survey methods

Various survey methods have been used to assess the impact of logging on reptiles in Australia. These include pitfall trapping (Webb 1995, Daly and Lemckert 2011) and searches for animals along transects (Lunney *et al.* 1991, Brown and Nelson 1993, Goldingay *et al.* 1996, Newell & Goldingay 2004, Daly and Lemckert 2011). Daly and Lemckert (2011) indicate that in studies that rely on transect searches there have been different methods used to obtain adequate replication. In surveys such as the Dorrigo assessment there was repeat sampling of sites, but in other surveys a greater number of sites have been sampled to gain adequate data for statistical analysis (Newell & Goldingay 2004). However, irrespective of sampling strategy, results from the above case studies indicate that only common species are seen in large enough numbers and at sufficient sites to allow univariate analysis of individual species. In all assessments of the impacts of logging in NSW undertaken for the Forest EIS process, none gathered sufficient information from transect searches to draw statistically meaningful conclusions on Threatened (*NPW Act 1974*) reptiles. In this survey no Threatened reptiles were found during the systematic surveys and only one Stevens' Banded Snake was observed opportunistically.

The Dorrigo surveys were one of the most labour intensive of the FMA surveys undertaken for the Forestry EIS process, both in terms of search effort per transect and repeat sampling of transects. These surveys allowed the abundance and habitat preferences of common species such as the Grass Skink and Scute-snouted Calyptotis to be assessed, but provided only presence/absence data on uncommon or rare forest-dependent species. We concur with Newell and Goldingay (2004) that although a key aim of the forest EIS process was to assess the response of individual species to disturbance (logging), few of the studies conducted actually achieved this. Data pooled from several forest EIS surveys (meta-analysis) and modern multivariate statistics has been used to explore logging effects on a greater number of species including those listed as threatened (Kavanagh and Stanton 2005). This analysis found that White's Skink, Friendly Skink *L. amicula*, Nobbi Dragon, Black Blind Snake, Short-limbed Snake-skink *Ophioscincus truncatus* and Jacky Lizard were disadvantaged by logging whereas the Swamp Snake, Land Mullet, Lace Monitor, Red-bellied Black Snake and Dwarf-crown Snake *Cacophis krefftii* were advantaged.

Seasonal reproductive activity of reptiles is an important factor to consider when designing quantitative surveys as studies conducted over the time when young are born or eggs hatch can greatly increase densities (Daly and Lemckert 2011). Reptiles in subtropical and temperate regions of Australia generally breed in spring and give birth or their eggs hatch in late summer to early autumn (Greer 1989). The assessment of this survey's results was not confounded by this variable as surveys were conducted during a period when common skinks had not given birth (e.g. Eastern Water Skink *Eulamprus quoyii*) or their eggs had hatched (e.g. Grass Skink).

Habitat specialists and zoogeographic patterns

We found that several groups of reptile species occurred in specific habitats. The saxicolous species that were highly associated with granite outcrops and granitic substrates included the Copper-tailed Skink *Ctenotus taeniolatus*, Eastern Crevice Skink *Egernia mcpheei,* White's Skink *Liopholis whitii* and the Dark Bar-sided Skink *Concinnia martini*. This association has been observed elsewhere on the Dividing Range in northern NSW (Daly and Lemckert 2011, Barker 1981). Granite outcrops are a significant reptile habitat along the northern-eastern NSW escarpment, including in the Dorrigo forests. However, it was noteworthy that the usually common Copper-tailed Skink was uncommon in this habitat, which may have been due to the relatively small areas of granite outcrops in the Dorrigo area.

Another group of reptile species were strongly associated with tall open forests with a closed mid-canopy. These mesic vegetation-associated species included the Land Mullet *Bellatorias major,* Murray's Skink *Concinnia murrayi* and Orange-tailed Shadeskink *Saproscincus spectabilis* (Sadlier *et al.* 1993, Swan *et al.* 2004).

Range extensions - limits of distribution

The Major Skink had not previously been recorded in the survey area and the recording of it during the surveys in Chaelundi SF represented a southern range extension. The Atlas of Living Australia (searched May 2013) shows this species has now been observed as far south as Coffs Harbour (Murphy and Murphy 2011). The Three-clawed Worm Skink *Anomalopus verreauxii* is also close to its recorded southern limit in the Dorrigo forests (Atlas of Living Australia - searched May 2013).

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APPENDIX 1

Location of sites surveyed, logging history, species richness and total number of reptiles and the two common reptile species.

Co-ordinates in GDA 94 Datum Zone 56. Note numbering of sites is consistent with those used by State Forests.

Forest type: GRG= Gorge Red Gum, BB = Blackbutt, MH = Moist Hardwood, NE = New England Hardwood, SG = Spotted Gum, SCG = Scribbly Gum, DH = Dry Hardwood

Logging history: L = logged, U = unlogged

Site	Location	Easting	Northing	Logging history and Forest type	Total reptiles first survey	Total reptiles first survey	Species richness first survey	Species richness second survey	Total L. delicata first survey	Total L. delicata second survey	Total C. scutirostrum first survey	Total C. scutirostrum first survey
1	East Chaelundi	455104	6684638	LGRG2	4	6	4	4	0	1	0	0
2	East Chaelundi	451404	6693088	LGRG1	4	5	3	3	2	3	0	0
3	Mid Chaelundi	446284	6681588	LBB1	26	44	3	4	24	35	0	6
4	Mid Chaelundi	447754	6680888	LBB2	29	27	3	2	26	24	2	3
5	Wild Cattle Creek	478954	6662988	LBB6	76	23	4	3	72	8	2	14
6	Ellis	460104	6660068	LBB3	94	71	3	5	90	55	3	9
7	Wild Cattle Creek	473404	6665068	LBB5	12	29	3	2	6	20	5	9
8	Moonpar	465354	6658488	LBB4	106	24	2	3	102	22	4	1
9	Wild Cattle Creek	482504	6655838	LMH1	2	7	2	3	0	3	0	0
10	Wild Cattle Creek	476884	6661868	LMH2	4	7	2	2	0	0	0	0
11	Ellis	456984	6666468	LMH4	7	1	2	1	0	0	0	0
12	Marengo	445334	6669118	LMH5	11	18	3	3	2	0	0	2
13	Mid Chaelundi	442904	6684288	LMH6	3	28	2	2	0	27	0	0
14	Moonpar	464484	6657068	LMH3	8	9	2	2	7	8	0	0
15	Marengo	441354	6673038	LNE2	52	46	4	3	22	30	2	0
16	Ellis	460404	6665988	LNE3	20	34	2	5	3	16	17	14
17	Mid Chaelundi	441404	6686438	LSG3	23	165	2	3	19	154	4	9
18	Marengo	451234	6674118	LSG5	12	8	5	3	8	6	1	1

APPENDIX I

Site	Location	Easting	Northing	Logging history and Forest type	Total reptiles first survey	Total reptiles first survey	Species richness first survey	Species richness second survey	Total L. delicata first survey	Total L. delicata second survey	Total C. scutirostrum first survey	Total C. scutirostrum first survey
19	Mid Chaelundi	449004	6691368	LSG1	11	8	1	2	0	6	11	2
20	Mid Chaelundi	444704	6689938	LSG2	48	102	3	3	32	84	14	16
21	Mid Chaelundi	445734	6685988	LSG4	50	24	3	4	47	21	2	0
22	Marengo	445654	6674068	LSG6	50	71	3	3	17	51	28	16
23	Wild Cattle Creek	473654	6663738	UBB1	22	3	2	1	21	0	0	0
24	East Chaelundi	452634	6675818	USCG3	3	7	1	3	3	5	0	0
25	Moonpar	468604	6657318	UMH1	2	2	2	1	0	0	0	0
26	East Chaelundi	452904	6680288	UMH7	2	5	2	2	0	0	0	0
27	Wild Cattle Creek	475754	6671848	UBB2	7	0	3	0	5	0	0	0
28	East Chaelundi	449904	6678618	UBB3	25	13	3	4	8	7	16	4
29	East Chaelundi	451114	6679818	UBB4	44	55	2	3	31	40	13	13
30	East Chaelundi	452404	6678888	UBB5	8	64	4	3	1	36	4	27
31	Mid Chaelundi	445554	6681738	UBB6	18	29	1	2	18	28	0	0
32	Wild Cattle Creek	473564	6663538	UMH2	32	5	3	3	25	0	0	0
33	Chaelundi	434684	6691368	UMH5	0	2	0	2	0	0	0	0
34	Hyland	445254	6657088	UNE1	35	60	2	3	23	42	0	0
35	Chaelundi	435554	6684688	UNE4	9	12	3	5	2	4	0	0
36	Chaelundi	433984	6688388	UNE5	4	1	1	1	4	0	0	1

APPENDIX I

Site	Location	Easting	Northing	Logging history and Forest type	Total reptiles first survey	Total reptiles first survey	Species richness first survey	Species richness second survey	Total L. delicata first survey	Total L. delicata second survey	Total C. scutirostrum first survey	Total C. scutirostrum first survey
37	East Chaelundi	452634	6684438	USG1	15	35	3	2	2	13	12	13
38	East Chaelundi	450254	6686568	USG3	15	22	2	3	3	7	12	14
39	Chaelundi	441104	6695818	USG5	20	13	2	3	0	8	11	4
40	East Chaelundi	451504	6678338	UMH8	19	14	4	4	3	8	10	4
41	East Chaelundi	450094	6677388	UMH9	14	4	2	2	1	2	13	2
42	East Chaelundi	452204	6678388	UNE7	19	96	3	4	0	2	0	0
43	East Chaelundi	450654	6678488	UNE8	47	65	3	5	19	54	26	5
44	East Chaelundi	450304	6683588	UNE9	38	30	2	2	19	13	19	17
45	East Chaelundi	453554	6678788	USG7	88	75	2	2	70	74	18	1
46	East Chaelundi	453604	6680838	USG8	12	116	3	7	9	108	2	2
47	East Chaelundi	454334	6682118	UDH1	61	79	2	4	7	20	54	52
48	East Chaelundi	453004	6680788	UDH3	5	6	2	3	3	1	2	3
49	East Chaelundi	454154	6683388	UDH5	47	42	5	3	4	8	39	32
50	East Chaelundi	454504	6682588	UDH6	26	23	2	4	5	2	21	18
51	East Chaelundi	455104	6680638	UDH7	9	37	2	4	5	28	8	3
52	East Chaelundi	455554	6680768	UDH8	9	20	2	3	5	15	4	4
53	East Chaelundi	450204	6676788	USCG2	29	12	4	3	13	9	13	0
54	East Chaelundi	449954	6685188	USG2	121	34	4	4	96	24	22	0
Total					1457	1738	139	160	884	1132	414	321

APPENDIX 2

Reptile species recorded from various surveys within State Forests of the Dorrigo Forestry Management Area

Note: taxonomy follows Cogger 2014. Asterisk indicates reptiles observed. * indicates conservation priority species as per Scotts (1996)

Family	Species	Common Name	Chaelundi	Ellis	Wild Cattle Creek	Marengo	Moonpar	Hyland	Wildlife Atlas Records
Chelonidae	*Chelodina longicollis*	Eastern Snake-necked Turtle	*						*
	Emydura macquarii	Macquarie River Turtle	*						
Varanidae	*Varanus varius*	Lace Monitor	*		*				*
Gekkonidae	*Saltuarius moritzi**	Moritz's Leaftail Gecko	*		*				*
Pygopodidae	*Lialis burtonis*	Burton's Snake-lizard	*						*
	Pygopus lepidopodus	Common Scaly-foot	*						*
Agamidae	*Amphibolurus muricatus*	Jacky Dragon	*						*
	Amphibolurus nobbi nobbi	Nobbi Dragon	*			*			*
	*Hipsilurus spinipes**	Forest Dragon	*	*					
	Intellagama lesueurii lesueurii	Eastern Water Dragon	*						*
Scincidae	*Acritoscincus platynota*	Red-throated Skink	*						
	Anomalopus verreauxii	Three-clawed Worm Skink	*						
	Bellatorias major	Land Mullet	*		*				*
	*Bellatorias frerei**	Major Skink	*						*
	*Calyptotis scutirostrum**	Scute-snouted Calyptotis	*	*	*	*	*		*
	Carlia vivax	Lively Rainbow Skink	*						*
	*Concinnia martini**	Dark Bar-sided Skink	*						*
	*Concinnia murrayi**	Blue-flecked Forest Skink	*		*	*	*		*
	*Concinnia tenuis**	Barred-sided Skink	*						*
	Cryptoblepharus pulcher	Elegant Snake-eyed Skink	*						*
	Ctenotus robustus	Striped Skink	*						*
	Ctenotus taeniolatus	Copper-tailed Skink	*						*
	Cyclodomorphus gerrardii	Pink-tongued Lizard	*						*
	*Egernia mcpheei**	Eastern Crevice Skink	*		*				*
	*Eulamprus heatwolei**	Yellow-bellied Water Skink	*						

APPENDIX 2

Family	Species	Common Name	Chaelundi	Ellis	Wild Cattle Creek	Marengo	Moonpar	Hyland	Wildlife Atlas Records
	_Eulamprus kosciuskoi_*	Alpine Water Skink							*
	Eulamprus quoyii	Eastern Water Skink	*			*		*	*
	_Harrisoniascincus zia_*	Beech Skink	*						
	Lampropholis amicula	Friendly Skink	*					*	*
	Lampropholis delicata	Grass Skink	*	*	*	*	*	*	*
	Lampropholis guichenoti	Garden Skink						*	*
	Liopholis whitii	White's Skink						*	*
	_Ophioscincus truncatus_*	Short-limbed snake-skink	*	*	*				
	Saiphos equalis	Three-toed Skink	*	*	*	*	*	*	*
	Saproscincus spectabilis	Gully Skink	*	*	*		*		*
	Saproscincus mustelina	Weasel Skink	*						
	Tiliqua scincoides	Eastern Blue-tongued Skink					*		*
Boidae	_Morelia spilota mcdowelli_*	Carpet Python	*						*
Colubridae	_Dendrelaphis punctulatus_	Common Tree Snake							*
Elapidae	_Cacophis krefftii_*	Dwarf Crown Snake	*						*
	Cacophis squamulosus	Golden Crown Snake	*						*
	Demansia psammophis	Yellow-faced Whip Snake	*			*			*
	Hemiaspis signata	Swamp Snake		*	*			*	*
	Hoplocephalus stephensii	Stevens' Banded Snake	*						
	Notechis scutatus	Eastern Tiger Snake	*						*
	Pseudechis porphyriacus	Red-bellied Black Snake	*					*	*
	Cryptophis nigrescens	Small-eyed Snake	*	*					*
	_Tropidechis carinatus_*	Rough-scaled Snake	*						*
Typhlopidae	_Ramphotyphlops nigrescens_	Black Blind Snake	*	*					*
		Total Species	**43**	**9**	**11**	**7**	**6**	**8**	

APPENDIX 3

The Forest Dragon *Hipsilurus spinipes* was only found on one transect in Ellis State Forest during the systematic surveys

The Dwarf Crown Snake *Cacophis krefftii* was only found during targeted surveys in Chaelundi State Forest

APPENDIX 3

The Beech Skink *Harrisoniascincus zia* was only found during the targeted surveys in Chaelundi State Forest

The Major Skink *Bellatorias major* was only found in the Chaelundi and Wild Cattle Creek State Forests during the systematic surveys